



NORTH CENTRAL  
**CLIMATE  
SCIENCE**  
CENTER

**Department of Interior  
North Central Climate  
Science Center**

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**FINAL REPORT FOR  
U. S. Geological Survey Award No.  
USGS G13AC003922 / CSU 5-388290**

Project title: "Foundational Science Area FY'13 activities"

Principal Investigator: Dennis Ojima  
Institution of PI: Colorado State University

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Submitted by:

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## Public Summary:

The North Central Climate Science Center (NC CSC) funded research activities in order to provide pertinent climate information to natural resource managers in our region to evaluate impacts of climatic changes and to develop strategies to respond to changes affecting their natural and cultural resources. These funded activities provided improved climate data sets, such as the high resolution temperature dataset, derived data from the latest international climate projections. The NC CSC used this information and additional climate information to evaluate and assess impacts on ecosystem and natural resources. This information was generated in partnership with National Park Service managers, Native American leaders, and groups working with various non-governmental organizations, such as The Nature Conservancy. In addition, information on climate changes and impacts were incorporated into regional assessment efforts for the 3<sup>rd</sup> US National Climate Assessment (NCA) and for the Colorado Vulnerability Study.

Adaptation research efforts and development of strategies with various natural resource managers from federal (especially our Landscape Conservation Cooperative groups associated with our region), state, and Native American communities were carried out. NC CSC staff used surveys and interviews to gain insights in how various climate changes, especially those related to drought conditions, have been affecting their management practices. This information was important in guiding further research with our management communities related to what climate information would be useful, what impacts are being observed or of concern to these management entities, and what pathways are open to meet challenges related to climatic changes.

# Project Summary

The North Central Climate Science Center efforts have been framed as a Resource for Vulnerability, Adaptation, and Mitigation Projects (ReVAMP). **The vision for the NC CSC is a coordinated and integrated regional approach to the management of the nation's land, water, fish and wildlife, and cultural heritage resources that utilizes the best possible understanding of past, present, and future climate into the decision process.** This project has been funded to enable the development and application of ReVAMP to provide the understanding and information needed by decision makers and managers in the region so that a more complete understanding of potential impacts and adaptation strategies for a broad range of natural, cultural, and other resource management activities will be available.

The ReVAMP concept is designed to support information development and to establish partnerships with other funded projects and resource managers in our region to enhance their effectiveness. This funded effort has been led by university consortium members at Iowa State University, Montana State University, University of Colorado-Boulder, and Colorado State University (referred to as the North Central University Consortium or NCUC). The NCUC efforts are organized around three foundational research themes, which are meant to form an integrated approach to inform resource managers and researcher in our region:

- Understanding and quantifying drivers of regional climate changes,
- Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components, initial activity will be focused on ecosystem elements with the development of strategies to expand to the integrated system; and
- Characterizing vulnerabilities, adaptive capacity, and management response options of communities and natural resources.

The three Foundational Science Areas (FSA) are Climate Drivers, Ecological Impacts, and Adaptation.

The Climate Drivers FSA has engaged with the research and management community to develop climate information useable to our research and management partners. The data products include:

- Compiled daily historical and climate model (CMIP5) data
- Data used to estimate evaporative demand
- NC CSC paleo-environmental database
- TopoWx: Daily Gridded Historical Temperature Data and Derived Products, 1948-2012

The Ecological Impacts FSA used these data and additional environmental information to provide research and management partners information on:

- Valuation of WBP ecosystem services
- Cost/risk/benefit tabulation of whitebark adaptation plans
- Results summary for management decision-making
- Whitebark pine habitat suitability

The Adaptation FSA has developed research partnerships with our research teams and management partners to conduct assessments, interviews, and surveys, and host workshops to enhance our ability to develop adaptation efforts linked to the climate drivers and ecological impacts associated with our region. Information provided included:

- Historic and projected drought indices for DRAI case studies
- Drought Risk and Adaptation in the Interior (DRAI) interviews
- DRAI stories

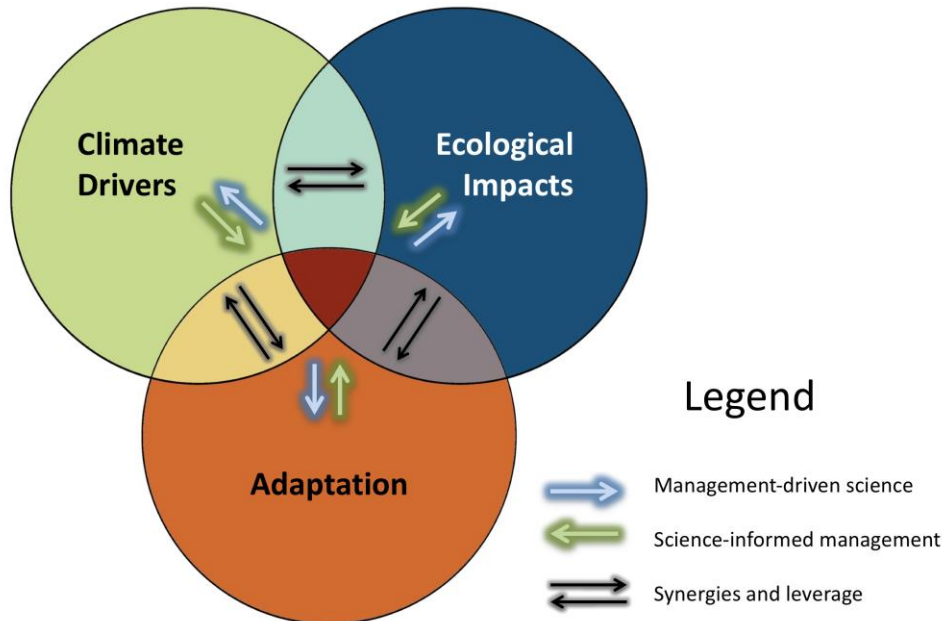
This information has been used in various publications, reports, management plans, and assessments.

# Introduction

The North Central Climate Science Center (NC CSC) is one of eight regional CSC's under the National Climate Change and Wildlife Science Center (NCCWSC). Our mission is "To provide the best available climate science and tools to inform natural resource management within the North Central domain." The NC CSC is a collaborative, applied research group that works with others across our domain to unite climate science with management decisions. The North Central University Consortium (NCUC), comprised of nine university partners in the region, provides foundational science needs and additional opportunities for integration with climate science users.

Starting in late 2012, the NC CSC initiated the first phase of the "Resource for Vulnerability assessment, Adaptation, and Mitigation Projects" (Figure 1) (Morissette 2012, North Central Climate Science Center—Science agenda 2012–2017: U.S. Geological Survey Open-File Report 2012–1265, 19 p.). The development of this operational framework emerged from our 2012 Strategic Planning Workshop held in Bozeman, Montana (<https://www.doi.gov/sites/doi.gov/files/migrated/csc/northcentral/upload/NC-CSC-science-planning-workshop-report-May-2012.pdf>). The ReVAMP concept is a centralizing theme that coordinates research done through the NC CSC and provides a mechanism by which the NC CSC can help serve stakeholder needs. The ReVAMP concept builds on three Foundational Science Areas led by the North Central University Consortium members. The three Foundational Science Areas offer an integrated approach to informing resource managers and researchers in our region:

- **Climate Drivers:** Understanding and quantifying drivers of regional climate changes.
- **Ecological Impact:** Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components.
- **Adaptation:** Characterizing adaptive capacity of communities and natural resources.



**Figure 1.** The three synergistic NC CSC foundational science areas include climate drivers, ecological impacts, and adaptation.

The project “Foundational Science Areas FY’13 activities” provides the building blocks of research approaches and tools for the ReVAMP efforts of the NC CSC.

### **Purpose and Objectives**

Our goal of this project is to provide usable information for decision makers and resource managers to better manage their cultural and natural resources under climate change. This goal of this project and the North Central Climate Science Center will be met through a set of objectives that will implement activities in support of “REsources for Vulnerability, Adaptation and Mitigation Projects.” The main objective is to:

- provide expertise and consultation on how the information from the three foundational science areas can contribute to the services and tools developed by the NC CSC to make that research both useful and usable to resource managers in the region.

This objective was further refined into these sub-objectives to guide the efforts in the FSA’s.

- understanding and quantifying drivers of regional climate changes;
- impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components;
- characterizing adaptive capacity of communities and natural resources; and
- providing the information to inform natural resource decision-making frameworks

### **Organization and Approach**

Research and analysis to meet these objectives are organized and implemented through three Foundational Science Areas (FSA; Figure 1). Activities in these FSA’s have included conducting research and engagement efforts to work more closely with the natural resource management and decision making communities in our region. These activities have been developed with input from the Landscape Conservation Cooperatives, members of the JSC, and other resource management entities in the region. This research project developed the initial framework to conduct research, synthesize knowledge, and create a platform for research and application dialogue.

The strength of this organizational structure is that it enables the ReVAMP effort to better support the research and the stakeholder communities.

We have a set of mechanisms to develop and deliver research activities with our stakeholders as part of the process. Collaboration between decision makers, the climate modeling community, and researchers within the NCUC enhanced the integration of relevant climatological, ecological, energy, cultural, and management disciplines. Specifically, NCUC research includes:

- Region-specific approaches for developing targeted climatological information that respects the full range of temporal and spatial scales of climate processes in order to understand vulnerability of conservation targets to changing climate and opportunities for renewable energy given future climate scenarios.
- Capacities to provide enhanced climate information at relevant spatial and temporal scales, both for historical climate and projections of future climate.
- Ecological response modeling with enhanced climate information that respects non-stationarity.
- Social-ecological vulnerability and adaptation response studies of the social-ecological system

In 2013, it was jointly decided to also work on a more integrated theme of drought across the region. This decision was based on the recognition that our region has recently experienced drought and that the exposure to drought is projected to increase across the region under continued warmer temperatures.

## **Project Results, Analysis, and Findings**

The project components are provided for each separate FSA.

### **FSA 1. Understanding and quantifying drivers of regional climate changes**

Understanding climate drivers is a central theme for all CSCs. Informing the north-central management community on the latest science related to climate drivers in the region and communicating the potential effects is a fundamental and critical element of the NC CSC ReVAMP. The climate in the north-central domain is driven by large-scale patterns in atmospheric circulation, the region's complex topography, and effects due to the nature of the local land cover. The multiscale nature of these climate drivers creates patterns of mean climate, climate variability, and climate change that are characterized by dramatic gradients in seasonal and annual temperature, effective moisture, and wind. The resulting climatic variability determines the diversity and distribution of habitats that support species and ecosystems and impacts the potential renewable energy resources for the area. It is necessary, therefore, to use region-specific approaches for developing targeted climatological information that respects the full range of temporal and spatial scales of climate processes in order to understand vulnerability of conservation targets to changing climate and opportunities for renewable energy given future climate.

### **Related Activities and Deliverables**

This research focus provides climate information across the region that will be tailored to resource management decision-makers' needs, as well as to inform researchers of the drivers of impacts across an array of natural and cultural resource areas, from species, to landscapes, biotic and biophysical resources, and ecosystems. This information will be analyzed over historical periods and will include projections of different scenarios of climate dynamics into the future.

Specific deliverables for the Climate Drivers team include the following:

- Paleo-environmental database: Drawing in large part on the work of Dr. Whitlock at Montana State University, the North Central Climate Science Center Paleo-environmental Database serves as an archive of Pleistocene proxy records, metadata and derivative products (e.g., chronologies, vegetation and climate reconstructions), and provides a resource for environmental research, facilitating data viewing, synthesis and joint analysis of multi-proxy datasets.
- TopoWx is a gridded dataset of daily ~800-m interpolations of minimum and maximum topoclimatic air temperature for the conterminous U.S., based on elevation variables and MODIS land skin temperature. This dataset was produced by Numerical Terradynamics Simulation Group at the University of Montana with funding from the Climate Drivers FSA.
- Evapotranspiration Research Activities across CIRES/NOAA, NIDIS & NC CSC funded projects
- Compiled daily historical and climate model (CMIP5) data
  - Data used to estimate evaporative demand
- Exploring methods to analyze complementary relationship between evaporative demand and actual evapotranspiration over the Northern Great Plains and how it affects local hydrological systems
  - Have analyzed 2000-2014
  - Extend approach using datasets that cover longer periods

During this funding cycle we were also able to hire a Climate Postdoc at CIRES/NOAA/Western Water Assessment to support efforts in the Climate Drivers FSA. The primary research focus is on Evapotranspiration Research. Dr. Candida Dewes was hired for the position, and she started on July 1, 2015.

## **FSA 2. Connecting climate drivers to management targets**

Whereas climate drivers are a fundamental research component for the CSCs, for most management issues climate is often not the primary concern. For example, land managers are more concerned about animal populations or ecosystem services than they are about changes or trends in annual average temperature or precipitation. Yet climate drivers are linked to the conservation targets of concern. This research element is directed toward understanding and quantifying that linkage through ecological response models. Ecological response models, as enumerated in Glick and others (2011) help bridge between climate information and management goals.

This research area looks at leveraging ongoing and active research and expertise in ecological response models where translational climate analysis can advance that work. The connection to management actions links this research area to the adaptation and decision-making research area listed below. The NC CSC is looking to build ecological response modeling that can both (a) be improved with enhanced climate information that respects non-stationarity and (b) serve management issues that have been prioritized by the stakeholders. The ReVAMP infrastructure facilitates the connections and interactions. The related research in this focus area must be open to and agile enough to iterate with both the climate-drivers research component and relevant resource management goals and objectives.

### **Related Activities and Deliverables**

The ecological impacts research area provided analysis of ecological vulnerability to different exposures and sensitivities of system components to climate effects and drivers to address the nature of the vulnerability. It builds on observations available in the region and utilizes an ensemble of models to enhance the understanding of vulnerability to natural and cultural resources in the region. The vulnerability framework provides an analytical process to identify exposures and sensitivities of a system together, as well as separate parts of the system. Analysis of vulnerability will incorporate regional and temporal aspects to inform managers and researchers about interactions between factors and temporal dimensions of these interactions.

Specific deliverables for the Ecological Impacts team include the following:

- A new postdoctoral associate was hired at Montana State University to take the place of Nathan Piekielek who moved to a new position (Lead: Hansen).
- A draft hydrological analysis of the Greater Yellowstone Ecosystem's montane meadow condition was performed using MODIS data and has been loaded into ScienceBase (Lead: Debinski).
- Species distribution maps and woody encroachment maps for montane meadows in the Greater Yellowstone Ecosystem have been created and loaded into ScienceBase (Lead: Debinski)
- A manuscript was published in Forest Ecology and Management entitled, "Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains?" in 2015 (Lead Author: Hansen)
- A manuscript was submitted entitled, "Projected future changes in spring snow pack and late summer soil water deficit suggest decline in habitat suitability for most forest species in the Greater Yellowstone Ecosystem, U.S." in May 2014 (Lead Author: Piekielek)
- A manuscript was published in Ecological Applications in April 2014 entitled, "Exposure of U.S. National Parks to land use and climate change 1900-2100" (Lead Author: Hansen)
- A technical report was completed for the USDA Forest service entitled, "The ecology and management of moist mixed-conifer forests in eastern Oregon and Washington: a synthesis of the relevant biophysical science and implications for future land management" (Lead Author: Stine)

### **FSA 3. Characterizing adaptive capacity of stakeholder communities and informing management options**

Connecting to decision makers is one of the main operating principles for the center and integral to its mission. This connection is not always obvious or automatic; it requires not only a strong research program but also a healthy infrastructure for transition, a strong interface with the user community, and continuous evaluation of the process (National Academy, 2000). This research area ensures that the NC CSC has these key components in place.

Adaptive capacity issues come into play in both the 2nd and 3rd steps of the Glick and others (2011) framework. Understanding and evaluating the adaptive capacity of social-ecological systems in the north-central region should be an integral component in the development of management strategies to deal with climate change. The vulnerability of natural resources and the adaptive capacity of the social-ecological system vary across the region due to local, State, Tribal, and regional accessibility to social-ecological capital resource assets. The science done through the NC CSC aims to work toward understanding the availability and use of capital resource assets in the region and how they are, or can be, used for implementing adaptive management practices. This understanding is critical in the development of useful and feasible management strategies.

To identify conservation targets and implement management options, it is imperative to understand the social-economic context and drivers. The NC CSC is very committed to identifying end users' needs and understanding and facilitating the incorporation of climate science into management decisions through quantitative decision support tools.

#### **Related Activities and Deliverables**

This focus area provided a critical analysis of how the different management entities represented on the Joint Stakeholder Committee (JSC) and across the region have an ability to implement adaptation and mitigation strategies. This analysis will evaluate the options available to these entities to both address the impacts on the system and identify potential vulnerabilities. This information will provide a framework to build capacity to cope or respond to different stressors.

Specific deliverables for the Adaptation team include the following:

- Developed a research approach to study drought based on the Social Ecological Systems Conceptual Framework that incorporates a bottom-up approach through grounded theory methods.
- Established collaborative tribal research efforts related to vulnerability assessment, managing for drought, and assistance in developing additional research and management activities. Active project efforts are underway with tribal members in Wind River, Wyoming, and drought reporting and early warning reports have been created for the Missouri River Basin tribes.
- McNeeley led the coordination of a workshop that took place on Oct. 21-22 at Fort Washakie, WY. Workshop sessions and discussion focused on local drought impacts and needs for natural resource management and decision making during drought, the availability of drought and water monitoring data, and on how the tribes could supplement state and federal monitoring programs.
- Continued consultation with the funded projects, such as the Natural Resource Management Decision-Making Under Climate Uncertainty Building Social-Ecological Resilience in Southwestern Colorado project
- Established new collaborative studies with the Colorado BLM (main BLM Contact: Bruce Rittenhouse). This effort initiated a social vulnerability assessment under climate change in relationship to the completed ecological vulnerability study undertaken by the BLM.



## Foundational Science Area Teams

### *Synergies and continuation of teams*

The NC CSC five-year science agenda is founded on the three focus areas described above. We have maintained work in these areas, continuing and building on the integrated work among the three foundational science teams, and have integrated that work into the other work at the center and in the region.

### *Financial support*

The initial foundational science work was funded in 2013, continued through 2014 (this report), and will continue through 2015. The NC CSC provides resources to each team. Each team has a leader who is responsible for organizing the work within that area as well as connecting the work within that area to both the other foundational science areas and into the ReVAMP science delivery mechanism. Team resources can support time for the team leader, a post-doctoral researcher, and team workshops. However, it is up to the team lead, working in collaboration with the NC CSC, to utilize the budget to maximize the impact of each team.

### *Selection of team leads and governance*

Long-term planning efforts on how the NCUC will be able to continue support of research efforts in the region will be carried out by the lead of these research elements. The team leads Dr. Imtiaz Rangwala (formerly Joe Barsugli) for climate (University of Colorado), Dr. Andrew Hansen for ecological impacts (Montana St University), and Dr. Dennis Ojima for vulnerability and adaptation responses (Colorado St University). These leads continue in their leadership role as it was being defined at the May 2012 science-planning workshop.<sup>1</sup> Their initial interest and work contributed to the NC CSC five-year plan.

The NC CSC hosted a joint meeting of the Foundational Science Area teams in February 2014. This meeting allowed the team leads and other project representatives to come together to discuss progress and opportunities for collaboration and cross-sharing of data.

### *Consultation to assist with directed work*

In addition to the specific funding dedicated to each team lead, the team leads act as consultants to the NC CSC for recommendations and insight on how to spend directed funds available through the center. In 2013 and 2014 the NC CSC spent approximately ½ of its research funds on solicited/competed work and maintained roughly ½ for directed funding. As competed funds are awarded, the foundational science team leads have been consulted with to help guide the use of directed funds to a) augment the work of the solicited projects and b) fill any critical climate-science research gaps.

### *Assistance with coordination*

The foundational science teams help to ensure coordination with other national and regional initiatives. Priority regional coordination opportunities include working with the NOAA's Western Water Assessment and Landscape Conservation Cooperatives. Priority national level coordination opportunities include working with NOAA's National Climate Projection and Prediction program, the National Climate Assessment (NCA; disseminating information from the 2013 NCA and helping prepare information for the 2017 NCA), and the National Center for Atmospheric Research (NCAR).

### *Support for the mission of the NC CSC*

Finally, it is the ultimate objective of the three foundational science teams to support the mission of the NC CSC to deliver the best possible climate-related science to regional resource managers. Currently, the lead investigators for each of the three elements (i.e., climate drivers, ecological impacts, and adaptation) routinely communicate on research efforts and prioritization of research activities to

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<sup>1</sup> <http://www.doi.gov/csc/northcentral/upload/NC-CSC-science-planning-workshop-report-May-2012.pdf>.

enhance the linkage of research products. This collaboration across elements improves efficiency, understanding and utility for use in natural resource management decision making. With the resources and objectives outlined here, the NC CSC hopes it will be possible to further enhance coordination among elements to develop a more integrated climate-ecological-social system framework.

Cross-project meetings (face-to-face and virtual) among the foundational research groups, other funded investigations, coordinated efforts, and management entities working with the NC CSC have been and will continue to be held to co-develop research products and translational material that is relevant, useful, and useable for natural resource management decisions. The foundational science teams are playing a major role in the development of this integrated synthesis of research products aimed at meeting natural resource management needs. An important product of this integrative activity will be the development of synthesis papers outlining the implications of climate change effects on natural resources in the region and the potential response options that may be feasible. In 2014 the focus was on writing manuscripts that were relatively contained within the individual foundational science areas. While the teams will continue to write manuscripts directed by their individual research directions, 2015 will see the teams collaborate more intensively as they progress in their integrative activities and data sharing to produce synthetic results and management recommendations.

## Capacity-building

In addition to its support for research efforts, we used additional resources to leverage efforts to participate in capacity-building efforts to share lessons learned from co-production efforts developed with our core funding of this project. Our efforts have allowed us to capitalize on an opportunity to improve outreach and capacity building by leveraging training that was already being implemented by the U.S. Fish and Wildlife Service National Conservation Training Center (NCTC).

The NC CSC is providing climate education opportunities and training through cooperation with the National Conservation Training Center (NCTC). The NC CSC is collaborating with the NCTC to provide regional offerings of climate-related courses, which greatly reduces travel costs, eliminates tuition costs for students and covers travel costs for those who require it. In April 2014, we hosted the NCTC Climate Change Vulnerability Assessment class (ALC3184) in Jackson, WY. We had 35 students from our region, HI, AK, CA, and UT, and we also collaborated with the NCTC and the US Fish and Wildlife Service Landscape Conservation Cooperatives (LCCs) in September, 2014 in LaCrosse, WI. We are excited to develop opportunities for ongoing engagement with our user community through this venue. The NC CSC also partnered with the NCTC to offer a tribally-focused “Climate-Smart Conservation” course in Rapid City SD, July 28-30, 2015.

In addition, NC CSC staff have been asked to participate in the NW Climate Bootcamp as observers and instructors to their program. Both Jeff Morissette and Shannon McNeeley have provided their expertise to that effort.

The FSA’s have assembled a team of researchers to lead integrated research activities to enable the NC CSC to provide climate-relevant information to guide decision-making in the region. That is, the NCUC is providing the scientific foundation to be used within the ReVAMP.

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National Academy. 2000. From research to operations in weather satellites and numerical weather prediction. Washington DC. National Academy Press, 189 p.

**1. OUTREACH:** *Describe all project-related outreach opportunities to date. Include a list of: Publications*

Guidance Documents

- Comparing two methods for incorporating climate change into impacts modeling "perturbing past history" vs. "jump to model space".
- How to interpret "model space" results in terms of the real world (e-mail correspondence with Helen Sofaer).
- Why standardized indices may not be good predictors for species distribution models.
- Climate Model Averaging and ANOVA-- understanding when and how to average climate model results in the context of variance among climate models due to the main sources of uncertainty (Colin Talbert).
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Journal Articles, Book Chapters, Reports

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### Workshops

- Workshop on Evapotranspiration in Ft. Collins, Colorado. This 1-day workshop (May 6, 2014) was intended to introduce a group of ecologists to issues surrounding evapotranspiration and how to best include it in our models of the impacts of climate change on species distributions and other ecological processes.
- Workshop organized on "High Resolution Climate Modeling for the Northern Great Plains" in Boulder, Colorado. We organized a 2-day workshop, September 24-25, on the application of high-resolution climate models (HRCM; 1-20km resolution) for socio-ecological adaptation in the NCCSC regions at the NOAA Earth Systems Research Laboratory in Boulder. Stakeholder outreach regarding future climate scenarios development
- Rangwala consulted and presented work on climate scenarios development to different

stakeholders including the Southern Rockies Landscape Conservation Cooperative (SRLCC), NCCSC funded scenario planning project in the Dakotas, the Aspen Global Change Initiative (AGCI) and the Great Lakes Integrated Sciences and Assessments (GLISA). This climate scenarios development approach is evolving from the work done on the NCCSC Southwest Colorado project. Rangwala is working on a manuscript related to this work for publication, and expect to submit this in early 2016.

- 2015-16 El Niño webinar. Rangwala presented a webinar on the emerging 2015-16 El Nino event and its potential impact on the North Central US, in coordination with the Climate FSA team, Jeff Lukas (WWA) and Andrea Ray (NOAA ESRL) on July 28, 2015.
- Adaptation Working Group Workshop: The goal of this workshop was to develop a research and engagement plan for the next 18 months. Specifically, we outlined a strategy to work more directly with decision makers and managers in our region. August 31-September 1, 2016, Fort Collins, Colorado.
- ITEP Tribal Climate Adaptation Workshop: McNeeley was an instructor and on the planning committee for an ITEP tribal climate adaptation workshop in Billings, MT, 5/18/2016-8/5/2016
- Rising Voices 2014-2016: McNeeley, Morissette, and Ojima represented the NCCSC at the Rising Voices conferences
- Eagle County “Community Conversations on Climate Change”, Edward, CO. March 17, 2016: Ojima was an invited panelist
- Southwest Colorado Project Workshops: McNeeley participated in 2 stakeholder workshops in Durango and Gunnison for the Southwest Colorado Social ecological climate resilience project, 4/4/2016-4/15/2016
- Workshop In September 2014, tribal representatives, scientists, and members of state and federal governments gathered in Rapid City, SD, the ultimate goal of which was to discuss drought and climate change, drought impacts, early warning systems and planning for extreme events with the Missouri River Basin tribes. The NCCSC led the coordination of an Inter-Tribal Buffalo Council (ITBC) pre-workshop Representatives from tribes throughout the Missouri Basin region and beyond attended.
- The NCCSC and other organizations are providing technical support to the Eastern Shoshone and Northern Arapaho tribes on the Wind River Reservation in Wyoming as they establish reservation-wide drought monitoring and planning. NCCSC’s Shannon McNeeley, Colorado State University and Gary Collins, Wind River Reservation, are the lead.
- McNeeley led the coordination of a workshop that took place on Oct. 21-22 at Fort Washakie, WY. Workshop sessions and discussion focused on local drought impacts and needs for natural resource management and decision making during drought, the availability of drought and water monitoring data, and on how the tribes could supplement state and federal monitoring programs. A follow-up workshop was held in March 2015 to finalize the summary and to do training on drought planning.

#### Presentations and seminars

- Chang, T., A. Hansen, N. Piekielek. 2014. Estimating future suitable bioclimatic habitats for whitebark pine in the Greater Yellowstone under projected climates. Society for Conservation Biology North American Congress for Conservation Biology July 13-16, University of Montana, Missoula, Montana
- Chang, T., A. Hansen, T. Olliff, M. Pillet. 2014. Relevance of Climate Suitability Analyses for GYCC WBP Management Strategies in GYE. GYCC WBP Subcommittee Workshop. Bozeman, MT October 2014
- Hansen, A.J. 2014. Assessing ecological vulnerability to climate change across the Great Northern LCC. Society for Conservation Biology North American Congress for Conservation Biology July 13-16, University of Montana, Missoula, Montana.

- Hansen, A.J. Which tree species are most vulnerable to climate change in the Northern Rockies? Climate Change Adaptation Regional Tribal Conference, Bozeman, MT. August 2014.
- Hansen, A.J. L.B. Phillips, T. Chang, N. Piekielek. 2014. Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains? Yellowstone Biannual Science Conference Mammoth, WY, October 2014.
- Hansen, A.J. 2014. Land Use Change in the Greater Yellowstone Ecosystem: Past, Present, and Possible Future Patterns and Consequences. Jackson Wildlife Symposium, Teton Science School, Jackson WY. Dec 2014.
- Rangwala I. (Mar 24, 2015). *Climate Scenarios for Southwest Colorado*. Webinar presented to the stakeholders of the NCCSC Southwest Colorado Project.
- Rangwala I. (Nov 16, 2015). *Climate Science for Ecological Impacts Assessment and Adaptation Planning*. Webinar presented to the participants of the Climate Adaptation Workshop.
- Dewes C., I. Rangwala, M. Hobbins and J. Barsugli. *Evaluating Evaporative Demand in CMIP5 Models and its Role in Characterizing Drought over the U.S. Northern Great Plains*. AGU Fall Meeting. 2015
- Rangwala I. and coauthors (Dec 15, 2015). *The Understanding of Elevation Dependent Warming from Climate Models*. AGU Fall Meeting (Invited Talk).
- Rangwala I. and coauthors (Dec 18, 2015). *Development and Application of Future Climate Scenarios for Natural Resource Management in Southwestern Colorado*. AGU Fall Meeting.
- Rangwala, I, and J. Barsugli, Foundational Science Area Climate Overview (May 20, 2015), NCCSC Open Science Conference, Fort Collins, CO
- Barsugli, J.J., and I. Rangwala (May 8, 2015) A Brief Introduction to Climate Modeling. Webinar presented in advance of the NCCSC Open Science Conference Training Course.
- Barsugli J.J. Climate Information Do's and Don'ts: (18 May, 2015). Presented at NCCSC Open Science Conference Training, Fort Collins, CO
- McNeeley, S., D. Ojima, T. Beeton (2015). Towards effective decision maker-scientist interactions: Lessons Learned on Effective Co-production of Drought Science and Decision Support Tools with the Wind River Reservation Tribal Water Managers. 2015 American Geophysical Union, San Francisco, December 14-18, 2015.
- Shannon McNeeley was invited to speak about working with tribes on vulnerability assessments National Conservation Training Center, Choctaw Nation of Oklahoma, October 26-28, 2015.
- Ojima, Senay, Hilinski, and Flynn (co-presenters) presented at The 101<sup>st</sup> Annual Ecological Society of America meeting on "What kind of Drought matters". 11 August, 2016
- Gioia, J.B.M., T.L. Even, S.M. McNeeley, C.N. Knapp, and T.A. Beeton (2016). Colorado BLM Social Vulnerability Assessment: Livelihoods, Management, and Climate Change. A Case Study from the Gunnison Basin of Colorado. International Symposium on Society and Resource Management (ISSRM), Houghton, Michigan, June 22-26, 2016.
- McNeeley presented at CSC Eco-drought meeting on drought work at USGS
- NCCSC/NREL/ESS Joint Seminar Series on "Managing for Climate Change". Fall 2016.

#### Webinars

- 7/21/2016—NCCWSC/NCTC Webinar-- McNeeley presented on coproduction with tribes at Wind River for NCCWSC/NCTC national webinar series
- Adaptation Working Group Webinar Series, monthly webinar where we invite a diverse cohort of stakeholders to listen, learn, and discuss work of the researchers affiliated with the Adaptation Working group at CSU. To see a list of all the workshop and webinar related activities from the Adaptation working group, go to: <http://nccsc.colostate.edu/adaptation-past-events>
- Shannon McNeeley, and Corrie Knapp, Western State University gave a webinar on the Colorado BLM Social Vulnerability Assessment they are co-leading. They discussed first steps and plans for

the social vulnerability assessment that will inform the Colorado state BLM office development of a statewide Climate Change Adaptation Plan, November 17, 2015.

- Shannon McNeeley gave a webinar about Co-producing Science and Tools for Drought Preparedness with the Wind River Reservation's Tribal Water Managers, July 21, 2016. Led by Shannon McNeeley, this talk presented project activities to date along with the valuable and transferable lessons learned on effective co-production of actionable science for decision making in a tribal context.
- Shannon McNeeley led a webinar about how NCCSC can support tribes in proposal development and research efforts, April 28, 2016.

#### Communications with decision-makers

- WRR Drought Preparedness Project: From the first discussions, to the proposal development, design, and implementation, this partnership has been highly collaborative and interdisciplinary to ensure the co-production of actionable science with, and for, the communities at WRR. It is driven by the information needs and drought priorities identified by the tribes, and by local expert knowledge and observations of drought and climate change impacts. The project has ongoing communication with multiple managers from the Tribal Water Engineer's Office, Wind River Water Resources Control Board, and other resource managers, tribal leaders, and producers. Communication is frequent (monthly calls between all science teams, project management team, etc.) throughout the report period and they were heavily involved in coproduction of all aspects of the project, including a proposal development to the NCCSC and decision support tools for drought decisions
- Colorado BLM social vulnerability assessment project has ongoing communication with Field Office personnel from the Little Snake and Gunnison field offices, BLM administrative staff in Denver, and collaborators at Western State University. The research was tailored to address management needs/research requests from the BLM administrative office (case studies were chosen due to ongoing research in these sites).
- The DRAI interviews included multiple managers in CO, SD, WY who were interviewed in 2013-2016 and management issues and scales important to local managers are central to our analysis of the data.

#### Data Products

- Compiled daily historical and climate model (CMIP5) data
- Data used to estimate evaporative demand
- NC CSC paleo-environmental database
- Historic and projected drought indices for DRAI case Studies
- TopoWx: Daily gridded historical temperature data and derived products, 1948-2012
- Drought Risk and Adaptation in the Interior (DRAI) interviews
- DRAI Stories
- Valuation of WBP ecosystem services
- Cost/risk/benefit tabulation of whitebark adaptation plans
- Results summary for management decision-making
- Whitebark pine habitat suitability